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The Philosophy of Vitalism in Modern Biology.

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The Session 1914-1915, which ends with this meeting, and which has been the first year of the Royal Society of W.A., will be for ever remembered in the history of the world. I feel, therefore, that I cannot pass to the main theme of my address without some reference to those events which have cast a cloud over all.

Just at the moment when we were congratulating ourselves that culture and the study of the Arts and Sciences were breaking down the barriers of distance and almost of nationality—just when we were receiving in our midst as our guests the delegates of the British Association for the Advancement of Science (the Australian meeting, 1914), and several prominent German, French, and other foreign scientists, hell seemed to break loose. Europe, since last August, has been torn to the heart by fighting such as the world has never before seen, and to the horror of civilised peoples war has appeared in a form which very few, indeed, ever expected. Our much-vaunted civilisation seems for a moment to be a thing of nought; science and art, except in so far as they may be useful in the service of butchery, seem to have been relegated to the background, and in some cases, even, education has been looked upon with suspicion. We may truly comfort ourselves with the heroism, the valour, and chivalrous conduct generally of the men and women of the British Empire in this time of trial. At least the spirit of courage and honour which built up our Empire lives to-day. Whilst recognising this, let us look at another aspect of the matter. I should fail in my duty as President of this society, whose aim is to advance the study of science in all its branches, if I did not emphasise the important part which has been played by science in the progress of our enemies. This is, however, a truth which has been hurled at the Britisher for many years now. Unfortunately the warnings have been practically unheeded. At the present time, commercial men are telling us that we must capture Germany's trade, and Chambers of Commerce are trying to suggest means. We should never have allowed Germany to gain much of this trade. We are told, for example, that the value of the colouring matters consumed in the United Kingdom per annum is £2,000,000, representing, at least, £200,000,000 of textile industries and employment for 1,500,000 workers. Nearly all these dyes come from Germany. The great dyeing industry has been lost to this country because we, as a nation, and our manufacturers in particular, have failed to recognise the value of science in their works. Great inconvenience has also been experienced owing to the absence of German glass. I need hardly give other examples, but I notice in last Saturday's paper a remark made by Lloyd George, in a great speech at Liverpool, which is worthy of notice. Speaking of the recent German successes, he stated "The battle had been won by the skilled industries of Germany and the superior organisation of the German workshops. The German triumph was due entirely to superior equipment and overwhelming superiority in munitions of war." What does this mean? Is the British Empire unable to match the Germans? Is the race that produced Priestly, Black, Boyle, Cavendish, Davy, Dalton, Faraday, Graham, Newton, Kelvin, Stokes, Maxwell, Rayleigh, Thomson, Darwin, Wallace, Huxley, amidst hosts of others famed in the world of science, unable to organise its industries which depend largely on the discoveries of the scientist? The public and the manufacturers suggest "Protection"—"Tariffs on German goods." What inability to grasp the position! Before we can satisfactorily shut out German goods we must make them ourselves, and if we *had* made such goods and kept up our position in the war of commerce, there would probably have been no German hammering away in Belgium and France to-day. The nation that succeeds in the struggle for existence to-day will be the one where valour, chivalry, and high morality are co-existent with knowledge. Knowledge is proving its power to-day on the battlefields of Europe and courage alone will not avail against the application of science and art.

We have failed in the past to recognise the value of science—I might almost say with truth, the value of the educated man. Important posts in the British Empire have been, and still are, filled often without considering the ability of the men appointed. The average man does not respect the teachers of the children of our Empire as much as he should. How can he do so when their wage, in many cases, is scarcely equal to that of the lumper? Good men with great ability will not devote themselves to science at the Universities when their remuneration, after years of study and practical research, is likely to be somewhere near £80 or £100 per annum.

A few words about the inaugural year of the Royal Society. I feel that I have not only been very highly honoured by selection as your first President, but that the council and members have shown a spirit in choosing newcomers to the State and the society to be President and Vice-President respectively, which is worthy of the greatest respect. It is indeed unfortunate for a President to be elected under such circumstances, for he cannot help but feel how great have been his shortcomings.

I must strongly urge the need of an increased membership. We want more of the professional scientific workers of the State to join those who are already members. We want also more of the keen amateurs, for it must not be forgotten that much of the advance in science has been due to hard-working amateurs.

One other point, we want much more suitable rooms. This is largely a question of funds, and it adds more force to the duty of every member to find additional support, and new members.

THE PHILOSOPHY OF VITALISM IN MODERN BIOLOGY.

I may be criticised for attempting, in the short time allotted for the reading of a paper, to add still more in the way of a discussion of Neovitalism. For excuse, I must plead that the investigation of life and the phenomena which distinguish living from lifeless matter is the fundamental problem of the biologist.

Looking around us, we recognise certain bodies as living; others we say are lifeless. Some of these lifeless bodies may once have been living, or at least may consist of substances which once formed part of living bodies—others never at any time have had any close relations whatever with living bodies. We speak of living bodies as organisms and classify them as animals and plants. There are, however, cases where we find it extremely difficult to draw a line between the state of living and that of non-living, and, as a matter of fact, it is only with difficulty that we can put into words our conception of life.

Leaving aside these problematic cases, we may study the substance of living organisms by—

(1.) A chemical examination, in order to determine the elements of which it is composed.

(2.) A microscopic examination, in order to discover its structure.

(3.) An investigation of its manifestations, which we recognise collectively as indicative of life.

We can then attempt to correlate composition, structure, and life phenomena.

The chemist has shown us that the elementary substances of which protoplasm is built exist and are quite common in non-living bodies around us. The microscope has its limits, but the wonderful advance in microscope technique during the last ten years has taken us far into the minute structure of living things. The phenomena of life have been observed under normal and also abnormal experimental conditions. The question that follows quite naturally may be put in the following words:—"Are the manifestations of life and the phenomena associated with living beings to be explained entirely by physico-chemical phenomena as now understood by us, or must we conclude that there is some non-material vital principle, or some new form of energy, or some other property of matter as yet unknown, which is peculiar to living substance and the living organism?" This is the ultimate problem of biology. The mysterious properties of living substance have appealed alike to the philosophers of ancient days and modern times. Yet, as Johnstone states in his Philosophy of Biology, the ordinary person unacquainted with the results of physiological analysis has probably no doubt in his mind that the human body is animated by a principle or agency which has no counterpart in the inorganic world, and the same might even be said of the anatomist, naturalist, and physicist unacquainted with details of physiological inquiry.

We biologists have, as our duty, to explain all that is possible of such explanation by those forms of energy and properties of matter that so far have been known to us. A general knowledge of the beautiful co-ordination met with in Nature might, and very often does, lead to the belief that something more than the physical forces is present to animate and sustain the dust of which we are made. Let us see then to what view the results of our combined knowledge lead us to-day.

The earliest attempts to explain the phenomena of life have been lost with the knowledge of the ancients. In the period 460-370 B.C., however, the followers of Hippocrates believed that an agent—the pneuma—controlled all vital phenomena in the organism. In the years that followed, two controlling powers were considered necessary—the vital spirits resident in the heart and the animal spirits which had their abode in the brain. Much more definite information can be gathered if we pass to the period A.D. 131-200, when Galen, the first physiologist, formulated a doctrine which, with his other works, remained untouched, unshaken and controlling, through the long slough of the middle ages. Galen was also a believer in the spirits as the cause of all phenomena in the living body. He added, however, another of these ruling powers—the Natural Spirits—to the two already mentioned. This third factor was supposed to reside in the liver!

The nature of the spirits is not exactly indicated, but it must not be assumed that this early physiologist regarded them as entirely metaphysical.

Through thirteen hundred years of stagnation and decay must we pass until the night once more gives way to the light of learning, and we reach the dawn of modern times. By a strange coincidence the particular branch of the new learning with which we are to-night concerned was heralded by the works of one Andreas Versalius, who was educated at Louvain. Louvain University was of great renown even in 1530. Who could have foretold that it would have been left for the German race, most arrogant concerning learning, to demolish that kind of culture they have not yet attained? I have not time to do more than mention the work of Versalius. We must pass to the researches of an Englishman—the immortal Harvey. With the discovery of the circulation of the blood by Harvey, the death blow was given to the doctrine of the spirits. Harvey's explanation of the blood flow was essentially mechanical, and this view of the famous physician of Charles I. opened up a path which was followed with brilliant success by succeeding physiologists.

Whilst Harvey was making his investigations on the living organism, the science of physics was progressing rapidly. Galileo had been made Professor of Physics at Padua just six years before Harvey had reached that place, and epoch-making discoveries had been made in a new school of exact science. About the same time, four years after Galileo reached Padua to be exact, and in the year 1596, there was born near Tours in France the man whom we may consider as the real father of the mechanistic conception of the organism. I refer to René Descartes. He was a great mathematician, but neither a physiologist nor anatomist. He studied both subjects, however, as an amateur and even wrote a popular treatise which might be called the first text book of physiology. The point to be emphasised here is that he wrote to show that the new views and laws of physics might be applied to the living organism, and that the human body might also be looked on as a machine. Nevertheless, Descartes found it necessary to add an additional factor to his machine which he called the "Rational Soul." The Soul was supposed to be concerned in all thought, intelligence, memory, sensation and imagination. It was apparently not at all necessary for the ordinary functions of the body.

We must pass very quickly over further historical details, but I must draw your attention to the growth of another school which introduced the knowledge of the chemists and combined the forces of physics and chemistry in an endeavour to explain the phenomena of life. At this period, however, the physicists and chemists were not able to do very much after all, and the unexplainable became the support of a theory of Vital Force which now for the first time burst forth in definite form. The theory of Vital Force was put forward by the followers of Haller (1708-1777). This force was supposed to control and be responsible for all physiological processes whilst chemical and physical forces were confined to the phenomena of non-living matter. The result was disastrous. The phrase Vital Force became sufficient, became in fact the actual explanation (a lazy and stifling explanation) of all difficult problems in physiology.

The last period to be referred to leads on to to-day. It coincides with the victories of physiological chemistry and may be said to have commenced with the synthesis of Urea, an organic compound formed only by organisms. This was achieved by Wohler in 1828, and the discovery greatly stimulated the chemical explanation of life phenomena. From this date physiologists have applied chemistry and physics with huge success to the study of living organisms, and one obstacle after another has been broken down until in the impetus of their success they have become almost all pronounced mechanists and have claimed the sufficiency of chemical and physical explanations for all the phenomena of life. The biologists, too, have been carried away and we see the mechanistic view put forward very strongly by Huxley, whilst more modern discoveries have led to the very extreme views held by Jacques Loeb. The modern work in experimental embryology has led in some cases to the belief that development of the organism is explainable by known physico-chemical laws, but many of the foremost exponents of this branch of biology are unable to agree with this and one of them, Driesch, is now, perhaps, the foremost advocate of a new vitalism. Bergson, whose philosophy has aroused fresh interest to-day wherever it has been studied, "rising into heights of metaphysics" proclaims that our conceptions of mechanism fail to explain life. There is a spirit of unrest abroad once more and we meet again a tendency here and there to consider the organism as something more than a machine. The old phrase Vital Force is, however, often disguised and appears in new form as Biotic Energy, Entelechy, Elan vitale, etc., although it must not be supposed from this that the terms mean exactly the same thing. It must be confessed that the exponents of new vitalistic theories are being subjected to a strong frontal attack, and the feeling of the other side is summed up pretty well in the following quotation from a work on embryology published very recently.[1] "Thus we are brought back to Pre-Darwinian days, to a position indeed more primitive than that of the early 19th century, for it is surely easier to conceive of an all embracing intelligence, whose myriad plans were realised in the different species, rather than of millions of uncaused and unrelated intelligences . . . . . Driesch offers no explanation whatever, and it seems to us that this final result is the *reductio ad absurdum* of his whole system." Verworn, the physiologist, writes[2]: "But so much is certain; an explanatory principle can never hold good in physiology with reference to the physical phenomena of life that is not also applicable in chemistry and physics to lifeless Nature. The assumption of a specific vital force is not only wholly superfluous but inadmissible." One other example and that comparatively recent. I have no doubt that many of you have Schafer's Presidential Address to the British Association at Dundee in 1912 still in your mind. In the course of his remarks on the sufficiency of physics and chemistry, he stated "Vitalism as a working hypothesis has not only had its foundations undermined, but most of its superstructure has toppled over, and if any difficulties still persist, we are *justified in assuming that the cause is to be found in our imperfect knowledge of the constitution and working of living material.*" I want to emphasise the

1. MacBride, Text-Book of E·bryology., Vol. I., Envertebrata. London, 1914.
2. Verworn, General Physiology (Eng. Trans.). London, 1899.

latter part of this statement. To my mind it sums up all that is vicious in the modern mechanistic attitude of physiologists and biologists. We are certainly *not justified in assuming anything* of the kind. We may say that, possibly, when we have more perfect knowledge, all can be explained by ordinary physico-chemical laws; but just so can the vitalists say that more perfect knowledge will indicate the impossibility of physico-chemical explanation.

Driesch, after a long and successful study by experiment, has formulated a theory of some importance in any discussion on vitalism. He expounded his theory in the Gifford lectures given at Aberdeen in the year 1907.[1] Yet not once in Schafer's address are those experiments or the conclusions of Driesch referred to. We are simply led to assume that from the success in explaining some vital processes by physics and chemistry we must take for granted that all vital phenomena will be some day similarly explained. This is not a scientific attitude.

One might well use Johnstone's words[2] in reply to the physiologists—"Did physiology, that is the physiology of the schools, ever really investigate the organism? A muscle nerve preparation, an excised kidney through which blood is perfused . . . . . these things are not organisms." It seems very probable indeed that many of the changes taking place in the living body are purely chemical changes, and that many organs are operated by physico-chemical processes. We must, however, guard ourselves from confusing the cause and controlling factor or factors with the means by which they act.

The phenomena of the living organism which call for explanation may be classified as follows:—

Group (a.) The phenomena dealing with the growth of the organism in the widest sense of the word—that is to say inclusive both of development from the egg, and the regeneration of lost parts.

Group (b.) The phenomena dealing with the evolution of the species—transformism.

Group (c.) The phenomena of the actual functioning of the organism—the *modus operandi* of its organs—the methods by which energy is obtained for growth and upkeep.

The believers in the all-sufficiency of physico-chemical explanations have achieved their greatest successes in the study by experiment of the phenomena coming under Group (c.).

Their conception of life phenomena would compel us to regard the successive stages in the growth of the organism (Group (a.) above) as phases in a complex physico-chemical system. The same thing would apply to their explanation of the steps in the evolution of the species.

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[1] Driesch. Science and Philosophy of the Organism London, 1908.
[2] Johnstone. The Philosophy of Biology. Cambridge, 1914.

Let us glance at Driesch's illustration from the phenomena of Group (a.); the example which he has developed as a proof of Neo-Vitalism—the development of the sea-urchin's egg. The usual cleavage of the fertilised egg cell results here in first two and then four equal cells. Further segmentation gives, by equal division again, an eight cell stage. Driesch was able to show by separating the blastomeres (by shaking) that even in the eight cell stage, each blastomere was capable of producing a complete sea-urchin larva. After separation of the blastomeres in the following sixteen-cell stage (separation by the use of sea-water free from calcium), some of the isolated cells might yet survive and give rise to perfect larvae. The blastomeres in this case are, therefore, totipotent, or at least so up to the sixteen-cell stage. If we assume that a mechanism is present in the developing egg, the mechanism must be capable of division without destruction of the character of the whole, and must be present in each blastomere of the eight-cell stage at least. Let us follow the argument of Driesch still further. If cleavage is allowed to continue until the blastula stage is reached, this must possess a three-dimensional mechanism if we assume that a "kind of real machine" exists in the system "which if once set going, would result in the differentiations that are to take place." For a machine whose acting is to be typical with regard to the three dimensions of space must be typically constructed in regard to these dimensions itself. We can, however, cut the blastula in pieces and the parts will give rise to complete embryos. Can you conceive of a machine which can remain itself, if you remove parts of it or if you rearrange the parts at will? And Driesch has come to the conclusion that if we are to explain the development of the sea-urchin egg (which is a harmonious-equipotential system) by the action of physical or chemical factors, there must be some such thing as a machine.

Driesch's experiment, however, proves perhaps no more than that no mechanism such as is understood above can be present in the developing egg and embryo. The fact alone that part of a sea-urchin blastula can give rise to a complete larva does not seem to my mind to indicate very much more than the fact that the germ cell can give rise to a larva, for in both cases it is almost impossible to conceive of a series of chemical changes due to a certain initial chemical constitution being alone responsible for the regulation of development. And if it were found possible to explain the development from the egg as due to a chemical mechanism alone, it would be just as probable that the development of isolated blastomeres of the sea-urchin's egg could be explained by the same process.

Bearing in mind, then, the possibility of some other chemical mechanism, let us follow the development of the egg of another organism, for it will be found that the sequence of events described above is not universal and we should hope that our theory of development would apply to all cases. The development of the egg of

Cynthia[1] will prove very suitable for our purpose. There is no yolk in the young egg of Cynthia—the ovarian egg—and the neucleus is situated in the centre. The deposition of yolk takes place round another body to be found in the cytoplasm (probably the attraction sphere). A peripheral layer of cytoplasm remains free from the yolk, but pigment granules of a yellow colour are deposited in this region. During the maturation changes, nuclear sap flows upward and forms a cap of cytoplasm at one pole of the egg, in which the chromosomes may be seen lying. Whilst maturation divisions proceed, the clear nuclear cytoplasm and the peripheral cytoplasm with yellow pigment both flow down to the opposite pole of the egg. The result is that the slate-coloured yolk is now at the upper pole whilst clear cytoplasm with more internally situated yellow pigment is to be found collected at the lower. Further changes take place in the distribution of these different substances as fertilisation takes place. It will be seen, therefore, at the outset, that the structure of the egg is not homogeneous and that different substances are actually visible.

The first cleavage divides the egg into two equal cells. The second cleavage results in four cells, but the yolk is separated so that it all passes into two cells only. The third cleavage gives eight cells and the coloured substances are still further segregated. Two cells now consist almost entirely of grey yolk, two cells almost entirely of yellow pigment, and four cells contain almost only clear substance. For our present purpose it is not necessary to follow the remaining divisions.

Now some authors regard the sequence of events in this development as indicating that the coloured substances in the cytoplasm are definite organ-forming substances which cause and control chemically the phenomena of development. It was found by Conklin that if one of the first two blastomeres was killed, the other one segmented as if its sister were still present, and hence only half a larva resulted. If three blastomeres were killed in the four-cell stage, the survivor, whichever it might be, gave rise only to an imperfect larva. In fact, what developed out of the surviving blastomere corresponded exactly to what would have developed had the three sister blastomeres remained alive. It appears demonstrated, therefore, in this case, that the organisation present in the egg—whatever it may be—cannot be divided into equal parts which are totipotent. The factors of development seem, at first sight, to be different from those of the sea-urchin's egg.

If development in this way were universal it might appear quite easy to demonstrate the probability of a three-dimensional machine. It is not, however, necessary, to my mind (even if physico-chemical factors are regarded as sufficient) to prove the existence of a three-

[1] Conklin. Orientation and Cell-lineage of the Ascidian Egg. Journ. Acad. Sc. Philadelphia, Series 2, vol 13, 1905.

dimensional "machine" which has the characters of our machines of everyday life. We must look then at other chemical explanations which have been put forward. The best known is the Roux-Weissman, which assumes that a complicated structure built up of determinants, representing the characters to appear in development, is present in the egg, and that disintegration of the structure during development and the segregation of the determinants is responsible for the growth of the adult form. It will be obvious that this explanation alone fails to explain the experiments made by Driesch on the sea-urchin embryo. Removal of a blastomere should result in the loss of certain determinants or chemical substances, and consequently certain structures should be missing from the embryo. Subsidiary explanations have therefore to be added to account for these results and also for the phenomena of regeneration. The development of Cynthia would lend support to this theory if it were universal—but it isn't. Moreover, the experiments on the egg of Cynthia do not prove conclusively that the blastomeres have lost the power of producing complete embryos. The method of experiment alone may have prevented the full expression of their growth taking place. Did not Roux' famous experiment in 1888—the destruction of one blastomere of the two-cell stage in the development of the frog's egg—appear to prove conclusively the segregation of determinants? Roux found that if one of the two first blastomeres was destroyed by means of a red hot needle, the other continued to segment and finally gave rise to a half embryo—either a right or a left half according to which blastomere had been destroyed. This result led naturally to the assumption that the first division of the frog's egg was qualitative and separated the materials of the right half of the embryo from those for the left. Later investigations showed, however, that under other circumstances the two first blastomeres might give rise each to an embryo whose *complete* development was only prevented by the impediment offered by the presence of the other, whether living or dead. In the Newt, where the two first blastomeres can be separated, two whole larvae result. It is quite evident, therefore, that the potentiality of the two blastomeres is a question of constitution *plus something else.* The experiments on Cynthia eggs seem to me to be something like those of Roux on the egg of the frog. It is not yet evident from them that loss of certain blastomeres causes incomplete development *because certain substances are lost.* It is noteworthy that the blastomeres cannot be actually separated; it is only possible to kill different ones by means of a hot needle and note the development of the survivors. It is wonderful that the mutilated embryo is able to survive at all.

Quite apart, however, from the above, if we allow the assumption of numerous determinants, we have to account for the manner in which they are ushered to their proper places, repressed, or impelled to develope. We have to explain how it is that every part of an Echinus egg contains all the determinants or formative substances for the complete adult, since its parts (if it be divided in any way) can give rise to a whole embryo. It is inconceivable that there could be present in the protoplasm of any part of a sea-urchin's egg an individual and distinct chemical substance for every different part of the complex adult. To meet this difficulty, however, it has been assumed by some recent writers that there is only one chemical substance or very few to begin with and that these determine the development of other organ-forming substances later. The development of the egg of Cynthia is supposed to give much support to this theory.

If we consider that by the chemical changes or disintegration of a complex chemical compound (or a few complex chemical compounds) a definite sequence of events follows, resulting in the development of organic form, then how are we to explain the regeneration of lost parts in adult or embryonic organisms? Whence comes the re-existence of the compound or the "chemical state" to repeat its sequence when this has been completed once already?

It is to my mind quite illogical to assume, as MacBride has done, that the development of Cynthia proves the coloured masses to be definite organ-forming substances[1]:—"In the egg of *Cynthia partita* Nature has provided us with an ocular demonstration of the existence of organ-forming substances." If Conklin's experimental work is considered final enough to prove that parts of the segmenting egg are unable to regenerate the other parts, it does *not* prove that the coloured substances are organ-forming substances, nor that organ-forming substances alone can explain the organised development of form in the embryo.

What we see in the embryology of Cynthia suggests that the phenomena of development are accompanied by chemical reactions. This does not, however, necessitate the assumption that these same chemical reactions are the actual organising and controlling factors of development. Three differently coloured substances are present in the egg of Cynthia which are separated in development, and which appear to be associated with the production of certain parts of the embryo. It is possible that these substances are used in the construction of certain parts of the body without being in any sense factors of causation. Thus, as a matter of fact, the term "organ-forming substances" may be strongly criticised, for substances probably do occur which are used in the formation of organs without being the *cause* of formation of those organs. The metal of which church organ pipes are composed is an organ-forming substance, but we may put down in a heap, metal, wood, ivory, and reeds, and we shall never see them arrange themselves into a church organ.

I have devoted some little time to this discussion of the development of the organism. To what has it led? According to Driesch we are to conclude that something is present in the egg to co-ordinate,

[1] MacBride. Text Book of Embryology. Vol. I. pp. 631, 632.

to organise, and to harmonise the phenomena of development which is not material and which is not a form of energy. It is a conception for which Driesch has used the term Entelechy. For my part I consider the more correct attitude can be expressed by the statement of T. H. Morgan[1]:—"We cannot see how any known principle of chemistry or physics can explain the development of a definite form by the organism or a piece of the organism." We may consider this a fair result of the discussion of the events of animal embryology, but it must be emphasised that it is not a proof of the existence of any non-material factor. It does not mean that we may *never* explain development by material agency; it is merely the expression of our present ignorance of a factor or factors which are responsible for organising and co-ordinating, and which are characteristic of living protoplasm.

I shall pass over the phenomena of regeneration in the adult organism, but I may call your attention to the regeneration of the lens in the eye of the salamander after removal of this structure. The new lens arises from the already differentiated layers of the iris, whereas in normal original development it takes its origin from the ectoderm. That is to say, a highly specialised structure, the lens, arises out of a tissue which is highly specialised in another direction. Time will not allow of a discussion of this and other problems of regeneration here. Let us pass to the second group of phenomena that were mentioned at the outset:—The phenomena of Evolution or Transformism. During the past few years several writers on biological subjects, whilst accepting the general conception of Evolution, have hinted that they considered the explanations put forward as insufficient to account for the phenomena. For example, Bateson, in his Presidential Address to the British Association for the Advancement of Science last year at Sydney, used these words, "And the chief conclusion I drew was the negative one, that, though we must hold to our faith in the Evolution of species, there is little evidence as to how it has come about, and no clear proof that the process is continuing in any degree at the present time." This statement came, I am afraid, as a great shock to the general public and even to many scientists, especially to those non-biologists who have regarded Darwin's suggestions as all sufficient. It even resulted in newspaper correspondence suggesting that all evolution was a myth! I need scarcely point out that this was due to the very prevalent idea that Darwinism and Evolution are one and the same thing. It is only natural that with our modern technique and our accumulated knowledge of the phenomena of Nature we should endeavour to explain more fully the causes and methods of Evolution and to seek for explanations of the difficulties that Darwin himself felt in the acceptance of his theory. Let us leave on one side to-night the modifications to Darwin's theories now considered necessary owing to the

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[1] T. H. Morgan. Regeneration.

work of Mendel, Bateson, De Vries, and other experimentalists, and look at the difficulties which Driesch, and more lately Bergson, have found in the acceptance of the usual theories of descent. Driesch emphasises the fact (well known to biologists) that Natural Selection is not a creative factor. It does not explain the existence of certain animal and vegetable forms except by stating that all forms which *do not* exist are absent because they *cannot* exist or have never been produced. In the words of Driesch:—"Do we understand in the least why there are white bears in the Polar regions if we are told that bears of other colours could not survive." There is nothing in these statements, of course, which is contrary to the writings of Darwin. The point is merely emphasised that the Variations on which Darwin assumed Natural Selection to act are taken for granted. In other words no satisfactory explanation is forthcoming for the first appearance of Variations—the really fundamental phenomena of Evolution.

In addition, Driesch makes the criticisms that Darwinism cannot explain "the mutual adaptions between plants and insects; that it can never account for the origin of those properties that are indifferent to the life of their bearer; that it fails in the face of all portions of organisms which are composed of many different parts —like the eye—and nevertheless are functional units in any passive or active way; and that, last not least, it has been found to be quite inadequate to explain the first origin of all newly formed constituents of organisms even if they are not indifferent: for how could any rudiment of an organ which is not functioning at all, not only be useful to its bearer, but be useful in such a degree as to decide about life or death"?

The assumption that acquired characters could be inherited would, it is true, simplify, indeed it might explain, many of the above problems, and I see no reason yet for believing that acquired characters are not inherited. It would not explain all.

What does Driesch suggest as a solution of the problem? He considers that the non-material factor to which we have already been introduced, viz., Entelechy, is at the root of all transformism of species.

Bergson has evidently felt the same difficulties as Driesch and in his inimitable manner has devoted some time to an expression of the obstacles in the way of an acceptance of an accidental occurrence of co-ordinated variations. As one of the chief examples dealt with by Bergson is a structure on which I have spent some little time in research,[1] I feel no apology is needed for discussing the case here. The example comes from the well-known mollusc Pecten (the common Scallop), species of which exist all over the world. This animal, although in many details of organisation not very highly developed,

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[1] Dakin. The Eye of Pecten. Q.J.M.S. Vol. 55. 1910.

possesses a large number of remarkable eyes on the mantle edge. They are remarkable not only for their complexity, which is probably only approached by the Cephalopoda amongst the Mollusca, but for the large number present. The Eye consists of a vesicle, the wall of which is formed of the connective tissue of the thickened mantle edge. This tissue is reduced in thickness and is more transparent in front of the lens. Covering it at this place is the ectoderm of the mantle which is free from pigment and forms a cornea. Below the cornea and the underlying connective tissue is a cellular lens composed of rather peculiar cells. Across the optic vesicle is a septum which acts as the distal boundary of the retina and lies in contact with it.

Now the retina is highly characteristic. It comprises two separate and distinct layers of sense cells, and the optic nerve bifurcates before reaching the optic vesicle in order to innervate these two sensory strata. One series of cells—the distal of the two—is not unlike a layer of ciliated epithelial cells with the cilia-like processes directed towards the lens. The other stratum is thicker and consists of rod cells or retinophorae, bearing rods. These cells are inverted so that the rods are turned *away from* the lens. The nerve fibres reach the retinophorae by the periphery of the retina. The nerve fibres reach the distal layer of sense cells by perforating the septum.

By no stretch of the imagination can the structure or the development of this eye be said to resemble the human eye, except that both eyes have an inversion of sensory elements in the retina. Bergson, however, assumes (probably from an ancient loose biological description) that the eye of Pecten and the human eye are closely alike in structure.[1] Taking the view that the vertebrates and the molluscs separated long before the appearance of a visual organ so complex he asks "Whence, then, the structural analogy?"

The same author points out that an explanation of the evolution of *either* of these eyes by the selection of small variations, or large mutations involving many simultaneous small changes, is surrounded with difficulties. The organ will be of no use and will not give selection any hold unless it functions. It will, moreover, be of no use if the retina develop without the other parts of the eye. If then small variations are responsible how could they have arisen in every part of the organ at the same time and in such a way that the eye would, from the beginning, be able to perform its work? If large mutations have resulted in the evolution of the eye, then what factor has governed the development so that all parts of the sense organ, having changed, yet remain so co-ordinated that the function of sight is still observed? Let us grant the possibility, suggests Bergson, of such a state of affairs taking place in one or other of the cases referred to, out of myriads of failures—is it conceivable that such a process could have occurred twice in unrelated organisms if no special organising factor were present?

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[1] Bergson. Creative Evolution. (Eng. Trans.). London, 1913.

Now let us see how this may be answered. To my mind, in the first place there is nothing new in the case brought forward by Bergson except the difficulty of a similar evolution occurring twice and in unrelated organisms. The eyes, however, are *not* alike in structure. They certainly agree in being inverted, but even this inversion is different in type. Inversion occurs in other odd groups in the animal series and its isolated occurrence would suggest perhaps chance rather than design. A statement like the following:—"This inversion of the retinal layers occurs in all vertebrate animals but it is exceptional in the invertebrates" is very misleading at the outset, for it suggests to the reader that the two groups—Vertebrata and Invertebrata—are of equal rank and their subdivisions too.

We may regard similarity of structure in two invertebrate groups as surprising, but it would be much more extraordinary if we did not find similarity of structure in the different groups of the vertebrates, for they are much more closely related. In other details beyond inversion there are no resemblances between the two eyes, and consequently any special deductions drawn from the supposed occurrence of two similar complicated structures are quite worthless. Johnstone grants the failure of Bergson's argument in the case of the eye of Pecten, but suggests that a better case would be found in the convergent evolution of the teeth of "marsupials and some rodents." This cannot possibly be accepted, for on almost any theory of evolution it is to be *expected*, as suggested above, that similar modifications in structure will be found in different Vertebrate groups owing to their close relationship. As a matter of fact the teeth of marsupials and rodents are homologous structures and any resemblance is a case of parallelism. Convergent evolution is a different thing altogether.

We are thus left with Bergson's general objection that Natural Selection could not have resulted in the evolution of such a complex structure as an eye. This very example was brought forward by Darwin himself and answered in the "Origin of Species." Darwin writes:—"To suppose that the eye, with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by Natural Selection, seems, I freely confess, absurd in the highest possible degree. Yet reason tells me that if numerous gradations from a perfect and complex eye to one very imperfect and simple, each grade being useful to its possessor, can be shown to exist; if, further, the eye does vary ever so slightly, and the variations be inherited, which is certainly the case, then the difficulty of believing that a perfect and complex eye could be formed by Natural Selection, though insuperable by our imagination, can hardly be considered real. He who will go thus far, if he find on finishing the treatise that large bodies of facts, otherwise inexplicable, can be explained by the theory of descent, ought not to hesitate to go further, and to admit that a structure even as perfect as the eye of an eagle might be formed by natural selection—his reason ought to conquer his imagination." In this argument, or rather statement, Darwin takes his variations for granted, and it is in the production of these variations that both Driesch and Bergson believe their special factors manifest themselves. The whole thing is in reality only another form of the problem that we discussed first, *i.e.*, the development of form after the fertilisation of the ovum. The conclusions to be drawn from the discussions on the evolution of such a complicated organ as the eye are in a way disappointing. We can find no exceptional support, however, for Bergson or Driesch in the comparison, made so keenly by Bergson, of the eye of Pecten with the human eye. So far as the evolution of either of these eyes is concerned many biologists will follow Darwin and take chance variations as sufficient, if natural selection eliminates the useless, to account for the final evolution of such complex structures. Others would probably assert that nothing but large variations or mutations had been at work without attempting to inquire further into the co-ordination present in such mutations. The problem in either case is one of variation, and we have no evidence yet explaining the phenomena of variation. We are most certainly not in a position to say that some non-material factor such as Driesch's "Entelechy" or Bergson's "Vital Impetus" is present or even necessary, although no satisfactory mechanical explanation of variation is forthcoming.

Before leaving the subject which has introduced the eye of the mollusc Pecten into this discourse let me call your attention to one or two other points of interest in connection with the evolution of these structures. As a lamellibranch sense-organ the complexity of the eye of the scallop requires some explanation. I am afraid the theory of evolution by natural selection often encourages us to look with an anthropocentric attitude at the phenomena of adaptation. If so, we can find no solace in this case. There is no evidence of the need of such a battery of highly complicated visual organs. Other bivalves with similar habits are not provided with them. Lima swims as well as Pecten and has extremely simple eyes. Spondylus has eyes like Pecten and does not swim at all. Experiment, too (although personally I think in this particular example it is almost worthless unless the conditions are more natural than is usually the case) fails to show any reason for the presence of such eyes. How then are they to be explained on the assumption of a survival of the fittest, or on being the result of an active stimulus of the environment?

Subsidiary theories have been brought forward[1] to explain the evolution of monstrous reptiles, which were, by very reason of their specialised evolution unable to survive and are now merely indicated by those battered pages of history—the fossiliferous rocks. What

[1] Deudy. Momentum in Evolution. Report British Assoc. Adv. of Sc. 1911.

was the driving force in the evolution of all these forms and structures?

In conclusion let us look at the third category of phenomena suggested at the beginning of my address—the phenomena of the actual functioning of the organism—of physiology. Here we meet with evidence indicating the use of chemical reactions. In many cases, however, the phenomena observed appear at first sight to be highly peculiar. Take for example certain phenomena of osmosis. Several cases of diffusion in the animal body have been considered as beyond physico-chemical explanation because they appear to be contrary to what one observes in the laboratory or in the inorganic world. As Driesch states, the fact has been quoted often that the migration of ions or compounds in the organism can happen quite contrary to all the laws of osmosis, from the less concentrated to the more concentrated side of a so-called membrane, Driesch continues[1]:—"There is no simple membrane in the organism, but a complicated organisation of an almost unknown character takes its place and nothing, indeed, is against the assumption that this organisation may include factors which actually drive ions or compounds to the side of higher concentration which indeed drive them by "doing work," if we like to speak in terms of energy; and these factors included in the organisation may very well be of a true physical or chemical nature."

It is quite evident from this that Driesch looks upon physics and chemistry as explaining many processes that take place in the living organism, whilst at the same time considering them unable to account for all the phenomena of life. In the last few years physical chemistry has made progress in the elucidation of certain phenomena of osmosis, and it is interesting, perhaps, to note how an attempt has been made on physico-chemical lines to explain some of the phenomena met with in fishes.[2] In these animals the body fluids may possess a saline concentration which is normally higher than that of the surrounding water in which the fish are living (fresh water teleosts) or may be much lower than that of the external medium (marine teleosts). This appears at first sight very extraordinary for there seems nothing present to prevent simple osmosis taking place as it would if we separated a strong solution of salts from a weaker by a semi-permeable membrane. Experiments tend to show that the separating living membrane does not allow chlorine ions to pass through, although other experiments would indicate that it is to a certain extent permeable for them. The explanation of the problem is probably highly complicated. Donnan[3] has shown, however, that a membrane permeable to, say, Chlorine ions may actually separate two solutions with very different Chlorine concentrations. This

[1] Driesch. ibid p. 187.
[2] Dakin. Aquatic Animals and their environment. Intern. Revue d. ges. Hydrotrologie, 1912,
[3] Donnan. Theor. der Membrangleichgewichte. Leit. †. Elektrochemie. Bd. xvii.

would occur if an anion R′, and the undissociated salt NaR, were present on one side of a membrane impermeable to both, but permeable to NaCl which is present in solution on the other side. Owing to the presence of the non-dialysing substance NaR with the common ion Na the diffusion of the NaCl is hindered and in fact may be almost entirely prevented. Such mechanisms may be present in the living organism. There is no doubt, however, that the action of the membrane is different in aquatic animals immediately it is killed. But this could be put down to an alteration in its physical or chemical condition. This is only one example of the application of physico-chemical methods to the study of the phenomena of life, and it must be granted that these methods have elucidated much that once remained a mystery. We must not let ourselves be blinded by this success, nor must we fly to the opposite extreme and claim that the failure of our present knowledge to explain life phenomena means the presence of non-material factors.

To sum up, our conclusions are largely negative in character. The general result appears to be that "We don't know." Yet I think this result is not without value. The tacit acceptance of some explanation has often kept back discovery for years. One could use no better illustration of this than Stahl's famous theory of phlogiston which ruled natural science with a rod of iron for practically a hundred years. Curiously enough Stahl's hypothesis was vitalistic. The time is not yet ripe for a tacit acceptance of Entelechy nor of any other similar non-material factor in the phenomena of life. It is just as certain that it is too soon to take as proved or even as probable the view that ordinary chemico-physical phenomena are responsible for all that we know as life. In fact, our discussion has lent support to the presence of some unknown factor which is as yet hidden from our ken.

In the last few years a greater spirit of caution has been abroad —we are learning what complex phenomena we have to deal with in biological studies. The struggle to find simple theories has been carried too far. I might have said the struggle to find *a* theory, for scientists are often very intolerant, and it is sad to think of the wordy warfare that has raged on such problems as evolution, acquired characters, Mendelism, biometrics, and coral reefs and their origin.

Biology has had a remarkable effect upon human thought and action since the time of Darwin—let us then tread carefully, by experiment and observation collecting our facts, until the time comes when we feel our results allow of certain deductions being made. Then let us make them with a spirit of humility, being always prepared for newer knowledge to prove or disprove our contentions. I could not do better than conclude with the words used once by Professor D'Arcy Thompson: they meet our case so well:—

"The reasons and the reasoning that contented a past generation call for re-inquiry, and out of the old solutions new questions emerge; and the ultimate problems are as inscrutable as of old. In wonderment, says Aristotle, does philosophy begin, and more than once he rings the changes on the theme. Now, as in the beginning, wonderment and admiration are the portion of the biologist, as of all those who contemplate the heavens and the earth, the sea, and all that in them is."